

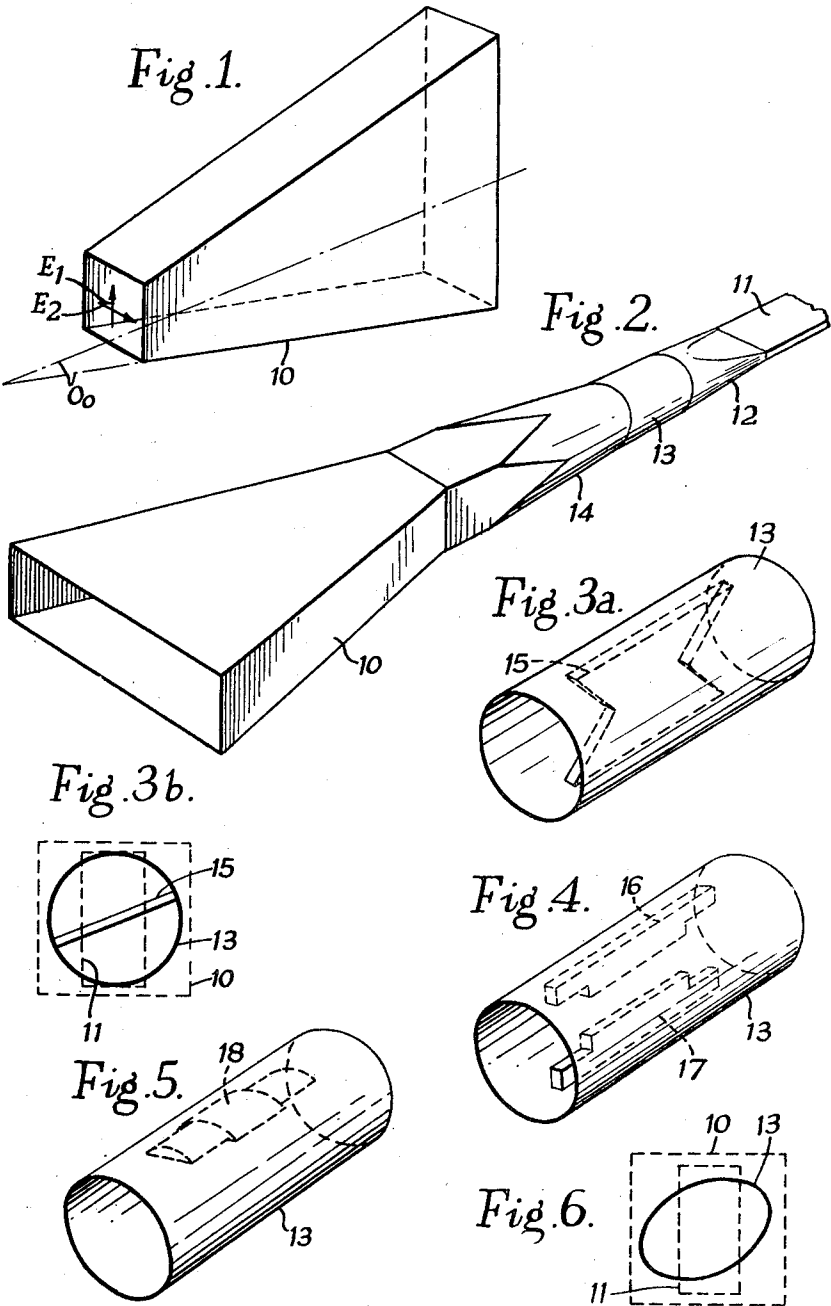
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ELECTROMAGNETIC WAVE RADIATORS

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ELECTROMAGNETIC WAVE RADIATORS

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The present invention relates to electromagnetic wave radiators for use particularly but not exclusively in radar systems.

Radar systems operating at very short wavelengths, for example 3 cms., suffer from a disadvantage that target indications are sometimes obscured by unwanted indications caused by reflections from rain.

To overcome this disadvantage it has been proposed to provide a radar system in which the radiated waves are approximately circularly polarised. The polarisation of such waves reflected from rain is substantially unaltered whereas the polarisation of such waves reflected from targets such as aircraft is markedly elliptical. At a receiver in the system means are provided for discriminating against the circularly polarised reflected waves.

One object of the present invention is to provide an improved electromagnetic wave radiator whereby approximately circularly polarised waves can be radiated.

According to the present invention an electromagnetic wave radiator for radiating approximately circularly polarised waves, comprises a horn of electrically conducting material and of rectangular cross section, and means whereby there can be fed into the throat of the horn in effect two orthogonal plane polarised waves of like wavelength λ , the waves being polarised in directions substantially parallel and perpendicular respectively to one edge of the throat of the horn, the throat and mouth of the horn being of different rectangular shapes and the dimensions of the horn being related to λ in such a manner that, in operation, one of the waves in travelling from the throat to the mouth of the horn is delayed by approximately $n\lambda/4$ relatively to the other wave where n is an odd integer. Thus at the mouth of the horn the waves are approximately in phase quadrature with one another and hence an approximately circularly polarised wave is produced.

In a preferred form of the invention the throat of the horn is of square shape, and the smaller dimension of the mouth of the horn is equal to the length of one edge of the throat.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which

Fig. 1 shows a horn radiator whereby approximately circularly polarised electromagnetic waves can be radiated,

Fig. 2 shows an assembly of a horn radiator as shown in Fig. 1 together with means for feeding electromagnetic waves into the horn, and

Figs. 3a, 3b, 4, 5 and 6 show alternative arrangements respectively of a part shown in Fig. 2.

Referring to Fig. 1, this shows a horn radiator 10 of rectangular cross-section. The horn may conveniently be of copper. The throat of the horn is of square cross-section each edge of the throat having the length a , and

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the mouth of the horn is of rectangular cross-section one dimension being a and the other s which is greater than a . Thus the horn is flared in only one dimension. Any suitable means may be provided for feeding into the throat of the horn two orthogonal, plane polarised waves of like wavelength λ , one of the waves being polarised in a direction parallel to the upper and lower edges (in the drawing) of the throat as shown by the vector E_2 , and the other wave being polarised in a direction parallel to the vertical edges of the throat as shown by the vector E_1 . The half-angle of the flare is θ_0 .

It can be shown that if

$$\theta_0 = \{1/(2n+1)\} \{f(\phi_1, \phi_2) + [f(\phi_1, \phi_2)g(\phi_1, \phi_2)]/[6\pi^2(2n+1)^2]\} \quad (i)$$

the radiation from the horn along the line of maximum gain is substantially circularly polarised.

In Equation i

n is an integer

ϕ_1 is such that $\cos \phi_1 = \lambda/2a$

ϕ_2 is such that $\cos \phi_2 = \lambda/2s$

$f(\phi_1, \phi_2) = (\phi_1 - \phi_2) - [(\sin \phi_1 - \sin \phi_2)/\cos \phi_2]$

$g(\phi_1, \phi_2) = 9 \operatorname{cosec} \phi_1 (\cos \phi_1 - \cos \phi_2)$

$-\cot^3 \phi_2 (2 + 3 \sec^2 \phi_2) + \cot^3 \phi_1 (2 + 3 \sec^2 \phi_1)$

In one example for use with waves of a wavelength of 3.2 cms. $a=1$ inch, $s=6$ inches and the length of the horn is 11.3 inches. A horn of these dimensions when used at a wavelength of 3.2 cms. produces a relative delay between the two waves of $7\lambda/4$.

For the purpose of feeding into the throat of the horn two orthogonal plane polarised waves polarised as shown by the vectors E_1 and E_2 , a number of alternative arrangements have been devised, each having the general form shown in Fig. 2.

In Fig. 2 the horn 10 is connected to a waveguide 11 of rectangular cross-section through three sections of waveguide 12, 13 and 14 respectively. The centre section 13 is of circular cross-section and one end of the section 14 square and is fitted to the throat of the horn and the other end is circular and is fitted to one end of the circular section 13. One end of the section 12 is circular and is fitted to the other end of the section 13. The other end of the section 12 is rectangular and is fitted to the waveguide 11.

In one arrangement having the general form shown in Fig. 2 the section 13 of waveguide of circular cross-section is fed from the waveguide 11 with a plane polarised wave in the H_{11} mode. The angular position of the waveguide 11 about its longitudinal axis is made such that the wave emerging from the section 13 and passing through the section 14 into the throat of the horn 10 is polarised with its E vector at 45° to the edges of the throat of the horn. This wave is resolved at the throat of the horn into the two waves required.

In another arrangement the section 13 of waveguide contains a phase shifter by means of which two H_{11} waves polarised at right angles to one another are produced. The two waves combine at the output end of the phase shifter to provide a wave polarised with its E vector at 45° to the edges of the throat of the horn. The wave is resolved at the throat of the horn into the two waves required.

The phase shifter can take various forms of which examples are shown in Figs. 3, 4 and 5 respectively.

In Fig. 3(a) the section 13 of waveguide contains a strip 15 of dielectric material. The two ends of the strip are tapered as shown for impedance matching. Referring to Fig. 3(b) this shows the orientation of the plane of the strip 15 relatively to the rectangular wave-

guide 11 and the throat of the horn. The angle between the plane of the strip 15 and the shorter sides of the waveguide 11 is made $22\frac{1}{2}^\circ$ and the wave in the rectangular section is arranged to be in the H_{01} mode. On entering the circular section 13 the wave changes to the H_{11} mode and is split into two H_{11} waves whose E vectors are respectively parallel and perpendicular to the plane of the strip 15. The length of the strip 15 is chosen to be such that the wave whose E vector is parallel to the plane of the strip is delayed $\lambda/2$ relatively to the other wave. The two waves combine at the horn end of the section 13 and produce the plane polarised wave rotated through 45° .

In Fig. 4 there is shown an alternative to the arrangement of Fig. 3. In Fig. 4 two metal fins 16 and 17 are used, the cut-away portions at the ends of the fins providing $\lambda/4$ transformers for impedance matching purposes. The orientation of the plane of the fins is made the same as the dielectric strip 15 shown in Fig. 3(b).

Yet another arrangement is shown in Fig. 5 in which the dielectric strip of Fig. 3 is replaced by a metal plug 18.

The use of the dielectric strip 15, the fins 16, 17 and the plug 18 can be avoided if the central region of the section 13 is made of elliptical cross-section. This can be achieved by means of a section of waveguide of circular cross-section provided with a clamp whereby the central region of the section can be squeezed into approximately elliptical shape. Referring to Fig. 6, this shows the orientation of the elliptical region relatively to the rectangular waveguide and the throat of the horn. The major axis of the ellipse is arranged to be at $22\frac{1}{2}^\circ$ to the shorter sides of the waveguide 11. In practice the clamp is adjusted for optimum conditions.

In any arrangement according to the invention circularly polarised waves can be generated only along the line of maximum gain of the horn. To obtain circular polarisation along the line of maximum gain the amplitudes of the two waves fed into the throat of the horn must be exactly equal and one must be delayed relatively to the other by exactly $n\lambda/4$ where n is an odd integer. If the amplitudes are unequal or if the delay is not precisely $n\lambda/4$ the radiated wave is elliptically polarised. It has been found, however, that a slightly elliptically polarised wave is more suitable for discriminating against rain than a truly circularly polarised wave. In practice an operator views an indicator and adjusts the ellipticity for maximum discrimination against rain.

In operation the use of approximately circularly polarised waves for discriminating against rain leads to losses and a substantial weakening of the wanted indications. It is desirable therefore that the system should be readily adjustable to enable either approximately circularly polarised waves or plane polarised waves to be used. The circularly polarised waves need then be used only when rain is present and at all other times plane polarised waves may be used.

Any of the foregoing arrangements may readily be adapted for this purpose. In the first described arrangement the waveguide 11 may be made rotatable about its longitudinal axis between a first position in which plane polarised waves are radiated and a second position in which approximately circularly polarised waves are radiated. When in the first position the broader walls of the waveguide 11 are parallel to the broader walls of the horn.

In the arrangements described with reference to Figs. 3(a) and 3(b) and Fig. 4, the section 13 of waveguide is arranged to be rotatable from the position described to a second position in which the strip 15 or the fins 16 and 17 as the case may be are parallel or perpendicular to the narrower walls of the waveguide 11.

Likewise in the arrangements described with reference to Figs. 5 and 6 the section 13 of waveguide is made rotatable between two appropriate positions.

Rotation of the waveguide 11 or the section 13 can be effected by remote control in any suitable manner. For example the section 13 may be mounted in ball bearings and a spring and stop member may be provided which normally position the section 13 to an angular setting in which plane polarised waves are radiated. A lever may have one end attached to the section 13 and the other to the armature of a solenoid. When the solenoid is energised it can be arranged that movement of the armature of the solenoid and hence the lever causes the section 13 to be rotated to a second angular setting determined by a second stop member. When in the second angular setting approximately circularly polarised waves are transmitted.

Although embodiments of the invention have been described in which the horn has a throat of square cross-section it will be understood that the throat may have other rectangular shapes. The criteria determining the dimensions of the horn are that the horn must permit the transmission therethrough of both waves fed into the throat of the horn and that one of the waves must be delayed by approximately $n\lambda/4$ relatively to the other wave.

We claim:

1. An electromagnetic wave radiator for radiating approximately circularly polarised waves, comprising a horn of electrically conducting material and of rectangular cross section, and means for feeding into the throat of the horn in effect two orthogonal plane polarised waves of like wavelength λ , the waves being polarised in directions substantially parallel and perpendicular respectively to one edge of the throat of the horn and of like phase, the throat and mouth of the horn being of different rectangular shapes and the dimensions of the horn being related to λ in such a manner that, in operation, one of the waves in travelling from the throat to the mouth of the horn is delayed by approximately $n\lambda/4$ relatively to the other wave where n is an odd integer the ratio of the height to the width dimension being continuously variable from the throat to the mouth of the horn.

2. An electromagnetic wave radiator according to claim 1, wherein the throat of the horn is of square cross-section and the smaller dimension of the mouth of the horn is equal to the length of one edge of the throat.

3. An electromagnetic wave radiator according to claim 2, wherein the means for feeding the two plane polarised waves into the throat of the horn, comprise means to feed a plane polarised wave polarised at 45° to one edge of the throat into the throat, the last said wave being resolved into the two waves polarised substantially parallel and perpendicular respectively to one edge of the throat.

4. An electromagnetic wave radiator according to claim 3, wherein the means for feeding into the throat of the horn the plane polarised wave polarised at 45° to one edge of the throat are adjustable to enable the plane of polarisation of the wave to be made parallel to one edge of the throat of the horn.

5. An electromagnetic wave radiator according to claim 4, wherein the means for feeding into the throat of the horn a plane polarised wave polarised at 45° to one edge of the throat of the horn, comprises a waveguide of circular cross-section connected between the throat and a further waveguide of rectangular cross-section, the two waveguides and the horn having a common axis.

6. An electromagnetic wave radiator according to claim 5, wherein the waveguide of rectangular cross-section is angularly adjustable about the said axis.

7. An electromagnetic wave radiator according to claim 5, wherein the waveguide of circular cross-section is angularly adjustable about the said axis and contains a

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strip of dielectric material mounted with its plane in the longitudinal direction of the waveguide.

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